

~~RESTRICTED~~ UNCLASSIFIED

Copy No. 10

RM No. A8A21

14 JUL 1948

NACA

15

**NACA**

# RESEARCH MEMORANDUM

THE EFFECTIVENESS AT HIGH SPEEDS OF A 10-PERCENT-CHORD

PLAIN TRAILING-EDGE FLAP ON THE NACA 65-210

AIRFOIL SECTION

By Richard J. Ilk

Ames Aeronautical Laboratory  
Moffett Field, Calif.

CLASSIFICATION CANCELLED

Authority J. W. Cronley Date 12/14/53  
CLASSIFIED DOCUMENT EO 105610

This document contains classified information affecting the National Defense of the United States within the meaning of the Espionage Act, U.S.C. 501 and 502. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law. Information so classified may be imparted only to persons in the military and naval services of the United States, appropriate civilian officers and employees of the Federal Government who have a legitimate interest therein, and to United States citizens of known loyalty and discretion who of necessity must be informed thereof.

1/11/54See NACAR 71963

## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON  
June 14, 1948

UNCLASSIFIED

~~RESTRICTED~~NACA LIBRARY  
LANGLEY MEMORIAL AERONAUTICAL  
LABORATORY  
Langley Field, Va.



UNCLASSIFIED

## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

## THE EFFECTIVENESS AT HIGH SPEEDS OF A 10-PERCENT-CHORD PLAIN

## TRAILING-EDGE FLAP ON THE NACA 65-210 AIRFOIL SECTION

By Richard J. Ilk

## SUMMARY

A high-speed wind-tunnel investigation has been made to determine the effectiveness of a 10-percent-chord plain flap on the NACA 65-210 airfoil section. For flap deflections ranging from approximately  $-12^\circ$  to  $12^\circ$ , section drag and lift forces were measured over a range of Mach numbers from 0.3 to about 0.875 for angles of attack from  $-2^\circ$  to  $8^\circ$ . Increments in section lift coefficient are presented as an indication of the lift-producing characteristics of the plain flap. More significantly, values of the section flap-effectiveness parameter are given as a measure of the effectiveness of the flap.

The test results indicate that at no speed within the investigated range does the lift increment for a given deflection of the 10-percent-chord flap fall below 50 percent of its low-speed value. A comparison of the effectiveness of the 10-percent-chord flap with that of a 20-percent-chord flap indicates that a reduction in flap-chord ratio from 0.20 to 0.10 lessens the severity of the effectiveness losses at supercritical speeds. The 20-percent-chord flap, however, remains more effective throughout the entire Mach number range of the present investigation.

## INTRODUCTION

Numerous wind-tunnel and flight tests have indicated that conventional airplane control surfaces experience a considerable loss in effectiveness at high subsonic speeds. Although analytical methods appear reasonably accurate in predicting the low-speed effectiveness of flap-type controls, reliable estimates of airplane control characteristics at high Mach numbers can only be made from pertinent experimental data. At present, the available experimental data are insufficient to allow quantitative estimates of the high-speed variation in control effectiveness with Mach number to be made for arbitrary airfoil control-surface combinations.

~~RESTRICTED~~

UNCLASSIFIED

The present investigation was undertaken to provide information on the control effectiveness of a plain trailing-edge control surface on a representative thin NACA 6-series airfoil. From a comparison of the variation in flap effectiveness with Mach number for the 10-percent-chord flap of the present report with similar data previously obtained in the Ames 1- by  $3\frac{1}{2}$ -foot high-speed wind tunnel for a 20-percent-chord flap on the NACA 65-210 airfoil, it was hoped that some conclusions regarding the effect of flap-chord ratio on high-speed control characteristics could be made. The present analysis has not considered the effects of differences in rigidity which would exist on the lifting surfaces of an actual airplane.

### SYMBOLS

$c_l$	airfoil section lift coefficient
$\Delta c_l$	increment in section lift coefficient due to flap deflection
$c_d$	airfoil section drag coefficient
$M$	free-stream Mach number
$\alpha_o$	airfoil section angle of attack, degrees
$\delta_f$	flap deflection, degrees
$\Delta\alpha_o/\Delta\delta_f$	section flap-effectiveness parameter, absolute value of the ratio of equivalent change in section angle of attack to change in flap-deflection angle at a constant section lift coefficient

### APPARATUS AND METHODS

All tests were conducted in the Ames 1- by  $3\frac{1}{2}$ -foot high-speed wind tunnel which is a low-turbulence, two-dimensional-flow, closed-throat tunnel.

Seven models of 6-inch chord were constructed of solid aluminum alloy to represent various deflections of a 10-percent-chord plain trailing-edge flap of true airfoil contour employed on the NACA 65-210 airfoil section. The actual flap deflections in degrees were -11.8, -6.8, 0, 1.7, 4.0, 6.9, and 10.6. The ordinates for the NACA 65-210 airfoil are given in table I and a sketch of a typical profile is shown in figure 1.

The models were mounted so as to span the 1-foot dimension of the tunnel test section. Each model was supported by circular end plates which were free to rotate with the model, meanwhile retaining continuity of the tunnel walls. Sponge-rubber gaskets were compressed between the end plates and the model to prevent end leakage and thus assure the measurement of section characteristics.

Lift and drag forces were obtained for each model at Mach numbers ranging from 0.3 to approximately 0.875 (with a corresponding range in Reynolds number from  $1 \times 10^6$  to nearly  $2 \times 10^6$ ) for airfoil angles of attack of  $-2^\circ$ ,  $0^\circ$ ,  $2^\circ$ ,  $4^\circ$ , and  $8^\circ$ . Airfoil pitching moments were also measured in the present tests but these moment data appeared to be of questionable validity because of temporary malfunctioning of the measuring equipment and hence have not been included in the present report.

The airfoil lift was measured by means of a manometer arrangement which integrated the tunnel-wall reactions along the floor and ceiling of the tunnel test section. Drag forces were measured by the wake-survey method in which a movable rake of total-head tubes was employed.

All data of the present tests, with the exception of characteristics measured at the choked-flow condition, have been corrected for tunnel-wall interference by the methods of reference 1. It has been demonstrated in this reference that under choked-flow conditions no equivalent free-air flow exists. Hence, the data obtained at the tunnel choking velocity cannot be corrected to free-air characteristics. Broken lines have been utilized to indicate that some uncertainty exists regarding the validity of data obtained at Mach numbers in the vicinity of the wind-tunnel choking Mach number.

## RESULTS AND DISCUSSION

The section drag and lift characteristics of the NACA 65-210 airfoil with a 10-percent-chord plain flap at various deflection angles are presented as a function of Mach number in figures 2 and 3, respectively. The variation of increment in section lift coefficient with flap deflection is shown in figure 4 for various Mach numbers and constant angles of attack. Lift increments for constant flap deflections have been cross-plotted for the same airfoil angles of attack given in figure 4 and are presented in figure 5 as a function of Mach number.

The data of both figures 4 and 5 indicate that the lift increments of the 10-percent-chord flap increase with Mach number, reaching a

maximum at a Mach number dependent upon airfoil angle of attack and magnitude of the flap-deflection angle. At any Mach number in the range from 0.3 to 0.875, the increment in lift coefficient produced by the 10-percent-chord flap is never less than 50 percent of its low-speed value for a given deflection.

For a plain trailing-edge flap, the control effectiveness can be evaluated from data which demonstrate the variation with Mach number of the flap-effectiveness parameter. This flap-effectiveness parameter  $\Delta\alpha_o/\Delta\delta_f$  is equal to the absolute value of the change in section angle of attack per unit change in flap deflection at a constant lift coefficient. For the present report, curves of section angle of attack as a function of flap deflection at constant lift coefficient were plotted for various Mach numbers. The absolute value of the average slope of each curve, from  $\delta_f = -10^\circ$  to  $\delta_f = 10^\circ$ , was taken as the flap effectiveness for a given lift coefficient and Mach number. The effectiveness parameter varies slightly with flap deflection and usually decreases as the deflection angle increases.

The effectiveness of the 10-percent-chord plain flap operating at moderate lift coefficients varies appreciably over a range of Mach numbers from 0.3 to 0.875. (See fig. 6.) At the lowest speeds the values of  $\Delta\alpha_o/\Delta\delta_f$  for the 10-percent-chord flap are approximately 85 percent of the theoretical value (reference 2) for thin airfoils. The flap effectiveness decreases gradually with an increase in Mach number from 0.3 to approximately 0.775, after which a more marked decrease is exhibited. The largest reduction in flap effectiveness, over the Mach number range from 0.3 to 0.875, is indicated from zero lift coefficient where the effectiveness has decreased to about 65 percent of its low-speed value. The variation between the experimental and theoretical values of  $\Delta\alpha_o/\Delta\delta_f$  may be attributed to the influence of viscosity, the effects of which are not considered in the theory. Since the rate of increase in boundary-layer thickness with flap deflection is usually greater than the rate of increase in boundary-layer thickness with angle of attack (reference 2), the slope  $\partial\alpha_l/\partial\delta_f$  is decreased more by viscosity than is  $\partial\alpha_l/\partial\alpha_o$ .

From a comparison of the variation in flap effectiveness with Mach number for a 10-percent-chord and a 20-percent-chord plain flap on the NACA 65-210 airfoil section (fig. 7), it can be seen that the loss in flap effectiveness at the highest Mach number is considerably less severe for the smaller-chord flap. Despite the abrupt effectiveness losses experienced by the 20-percent-chord flap at supercritical speeds, however, this flap continues to

remain more powerful than the 10-percent-chord flap up to 0.875 Mach number.

### CONCLUSIONS

From an analysis of the lift-control characteristics of a 10-percent-chord plain flap on the NACA 65-210 airfoil and from a comparison of the effectiveness of this device with that of a 20-percent-chord flap, also employed on the NACA 65-210 section, the following conclusions are indicated:

1. For a given deflection, the lift increment produced by the 10-percent-chord plain flap at Mach numbers up to 0.875 is never less than 50 percent of its low-speed value.
2. Although the effectiveness losses at supercritical speeds are considerably less severe for the 10-percent-chord flap than for the 20-percent-chord flap, the larger-chord flap retains greater effectiveness throughout the Mach number range from 0.3 to at least 0.875.

Ames Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Moffett Field, Calif.

### REFERENCES

1. Allen, H. Julian, and Vincenti, Walter G.: Wall Interference in a Two-Dimensional-Flow Wind Tunnel With Consideration of the Effect of Compressibility. NACA Rep. No. 782, 1944.
2. Swanson, Robert S., and Crandall, Stewart M.: Analysis of Available Data on the Effectiveness of Ailerons Without Exposed Overhang Balance. NACA ACR No. 14E01, 1944.

TABLE I

## ORDINATES FOR THE NACA 65-210 AIRFOIL SECTION

[Stations and ordinates given  
in percent of airfoil chord]

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
.435	.819	.565	-.719
.678	.999	.822	-.859
1.169	1.273	1.331	-1.059
2.408	1.757	2.592	-1.385
4.898	2.491	5.102	-1.859
7.394	3.069	7.606	-2.221
9.894	3.555	10.106	-2.521
14.899	4.338	15.101	-2.992
19.909	4.938	20.091	-3.346
24.921	5.397	25.079	-3.607
29.936	5.732	30.064	-3.788
34.951	5.954	35.049	-3.894
39.968	6.067	40.032	-3.925
44.984	6.058	45.016	-3.868
50.000	5.915	50.000	-3.709
55.014	5.625	54.986	-3.435
60.027	5.217	59.973	-3.075
65.036	4.712	64.964	-2.652
70.043	4.128	69.957	-2.184
75.045	3.479	74.955	-1.689
80.044	2.783	79.956	-1.191
85.038	2.057	84.962	-.711
90.028	1.327	89.972	-.293
95.014	.622	94.986	.010
100.000	0	100.000	0
L.E. radius: 0.687			
Slope of radius through L.E.: 0.0842			


 NACA

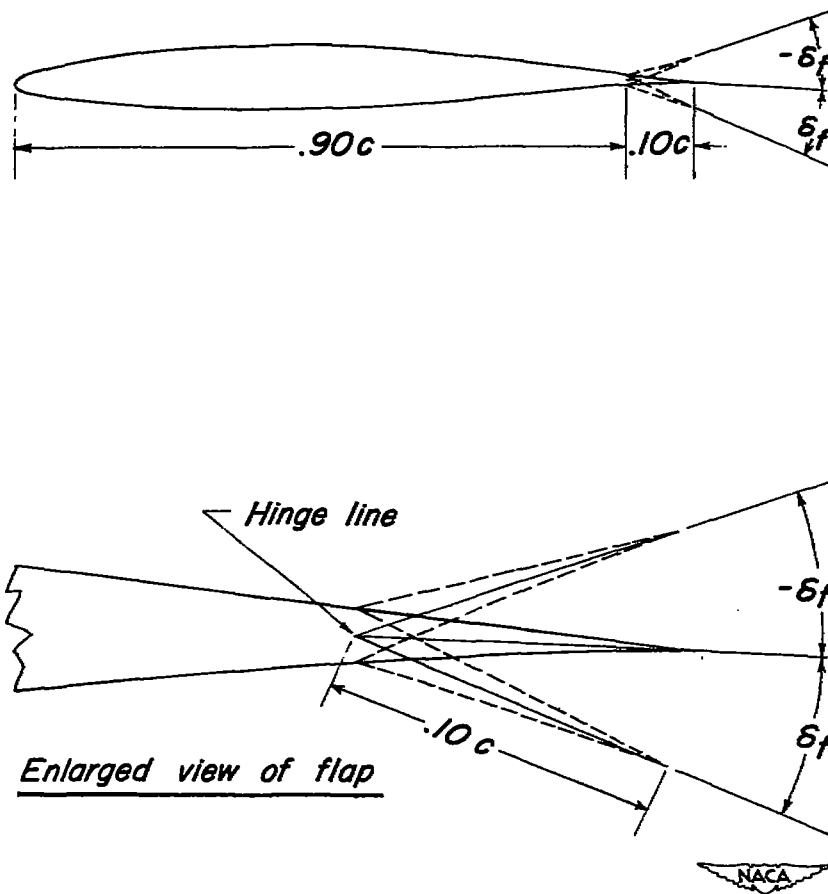
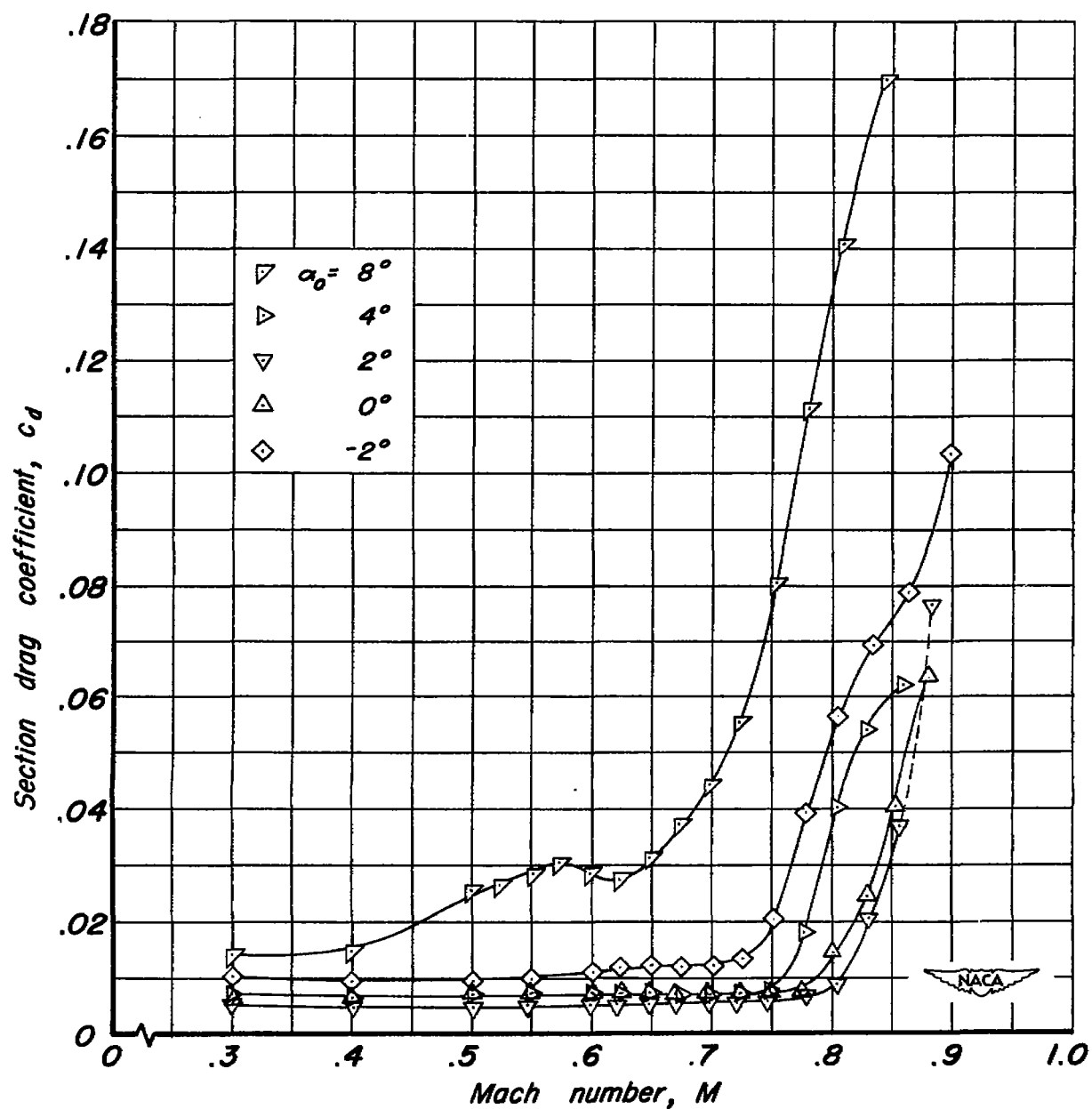


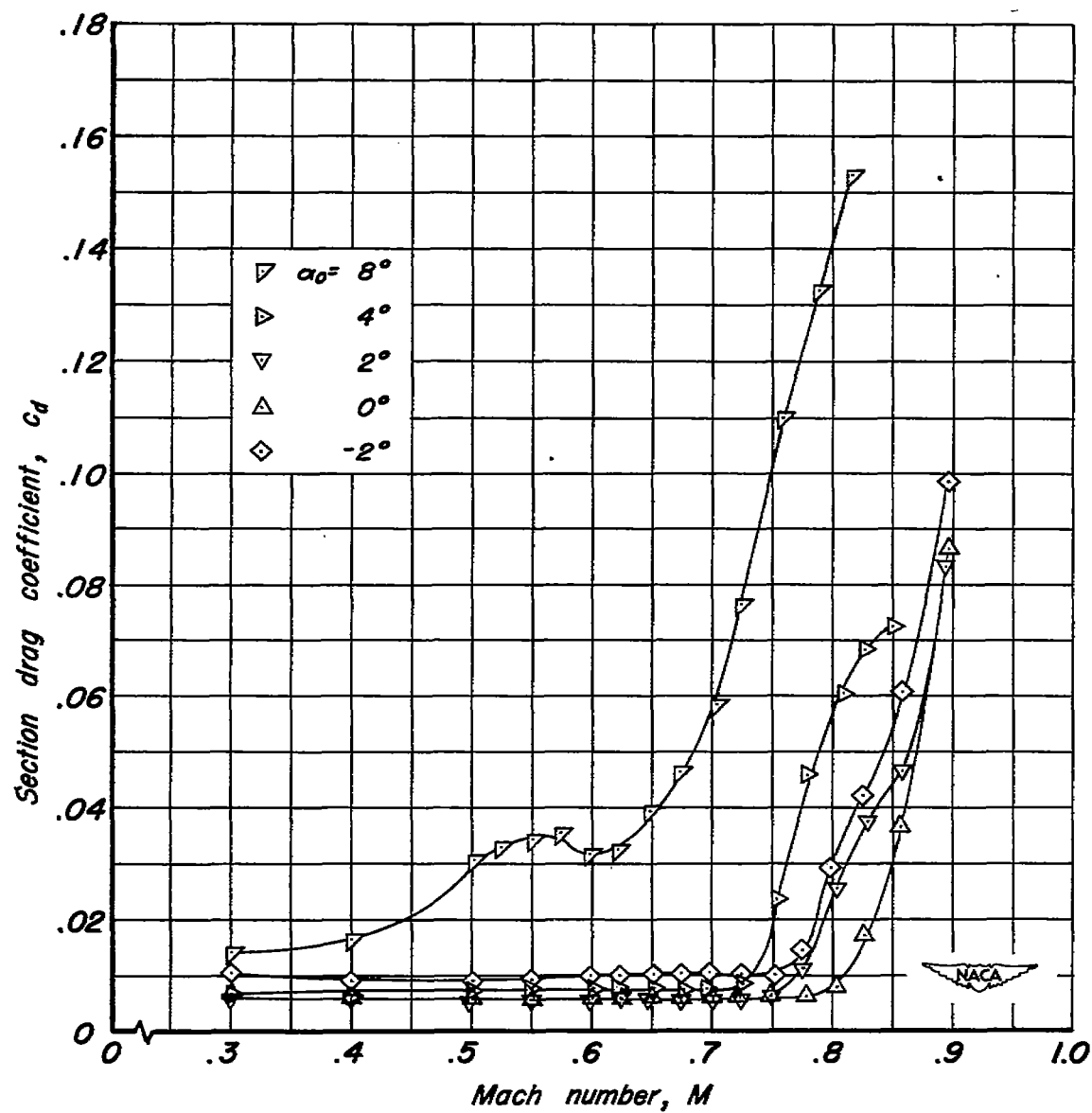
Figure 1: Typical profile of the NACA 65-210 airfoil section with 10-percent-chord plain flaps of true airfoil contour.





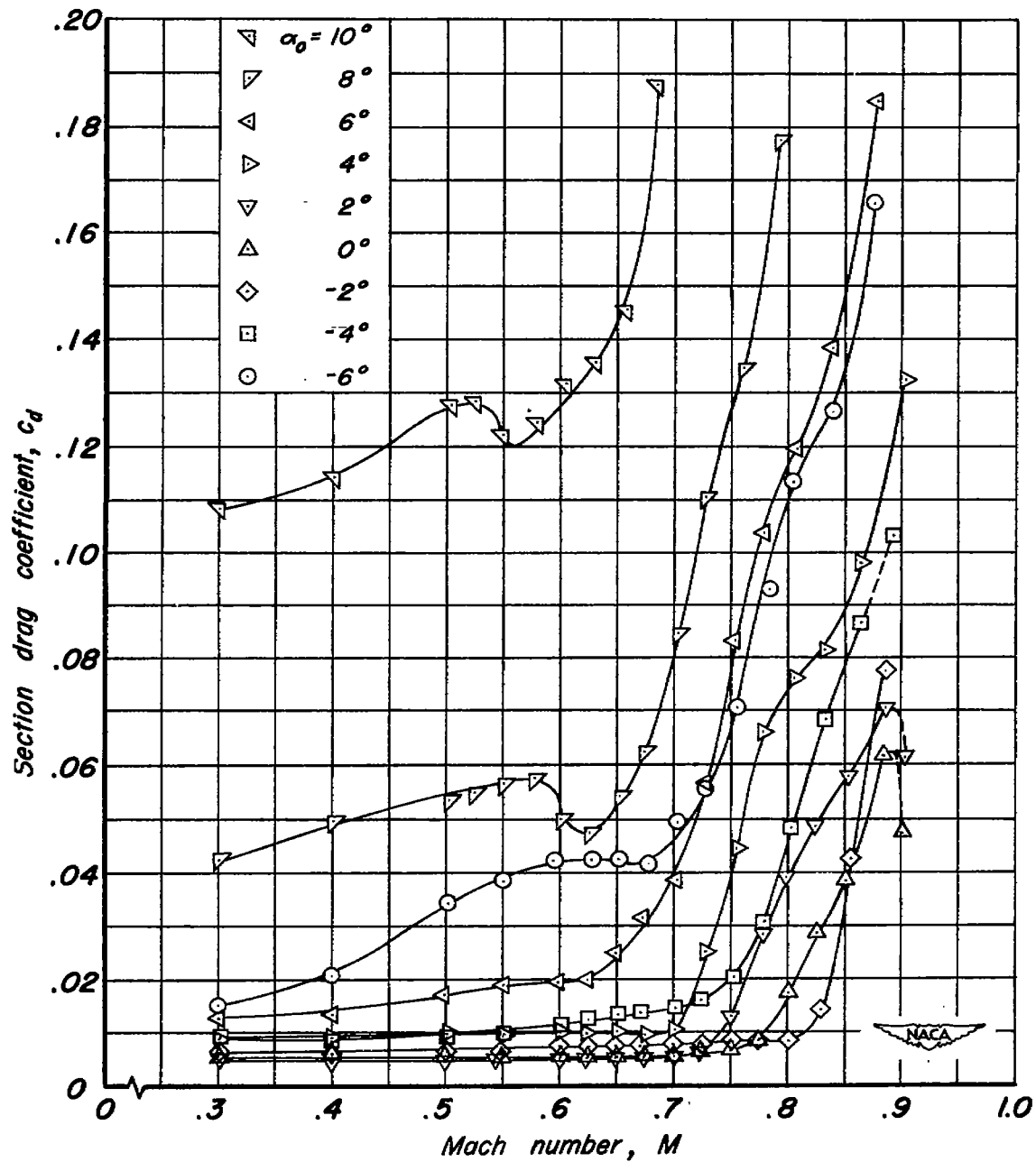
(a)  $\delta_f = -11.8^\circ$

Figure 2 :- The variation of section drag coefficient with Mach number for the NACA 65-210 airfoil with a 10-percent-chord plain flap.



(b)  $\delta_f = -6.8^\circ$

Figure 2 - Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.



(c)  $\delta_f = 0^\circ$

Figure 2: Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.

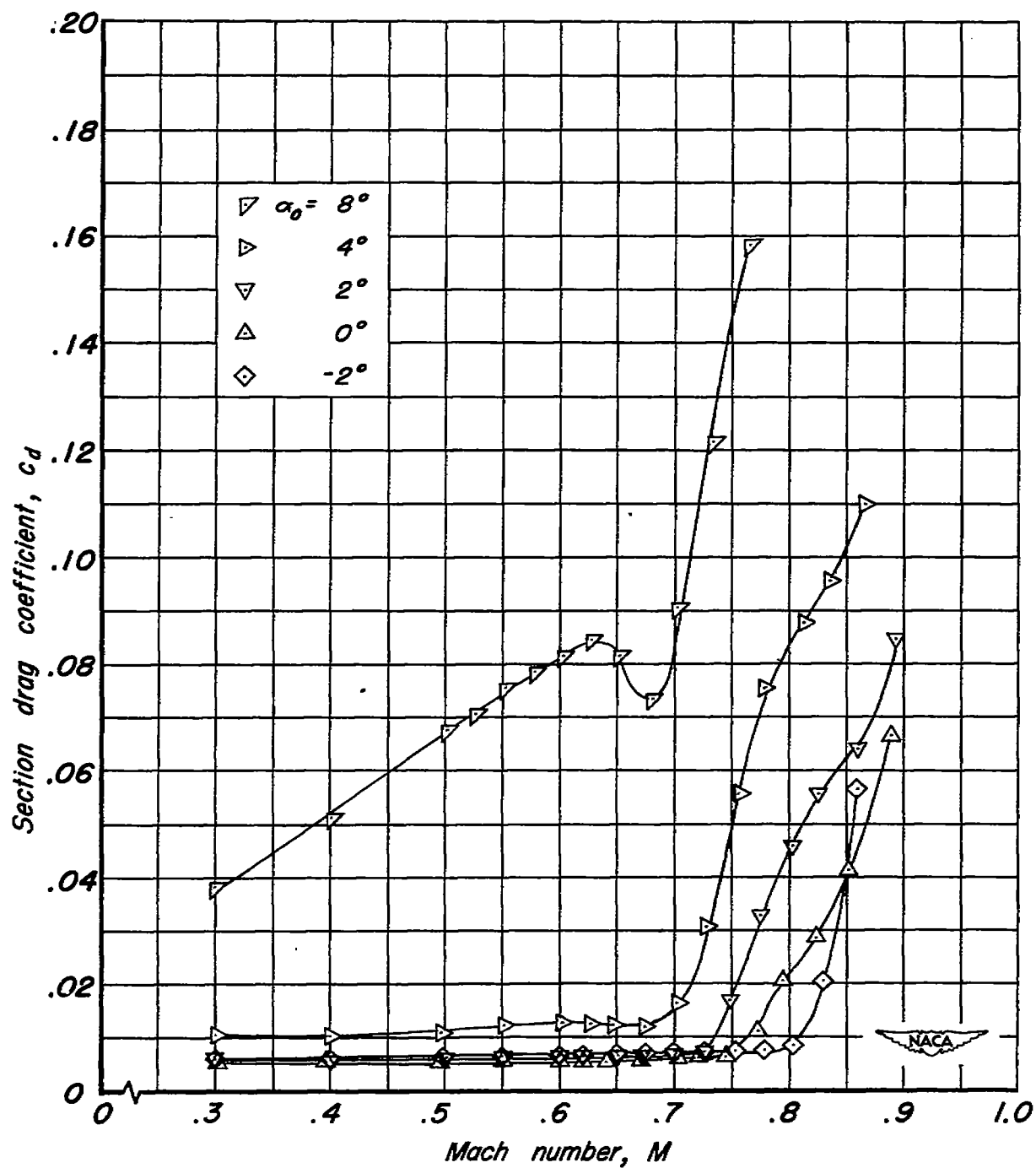
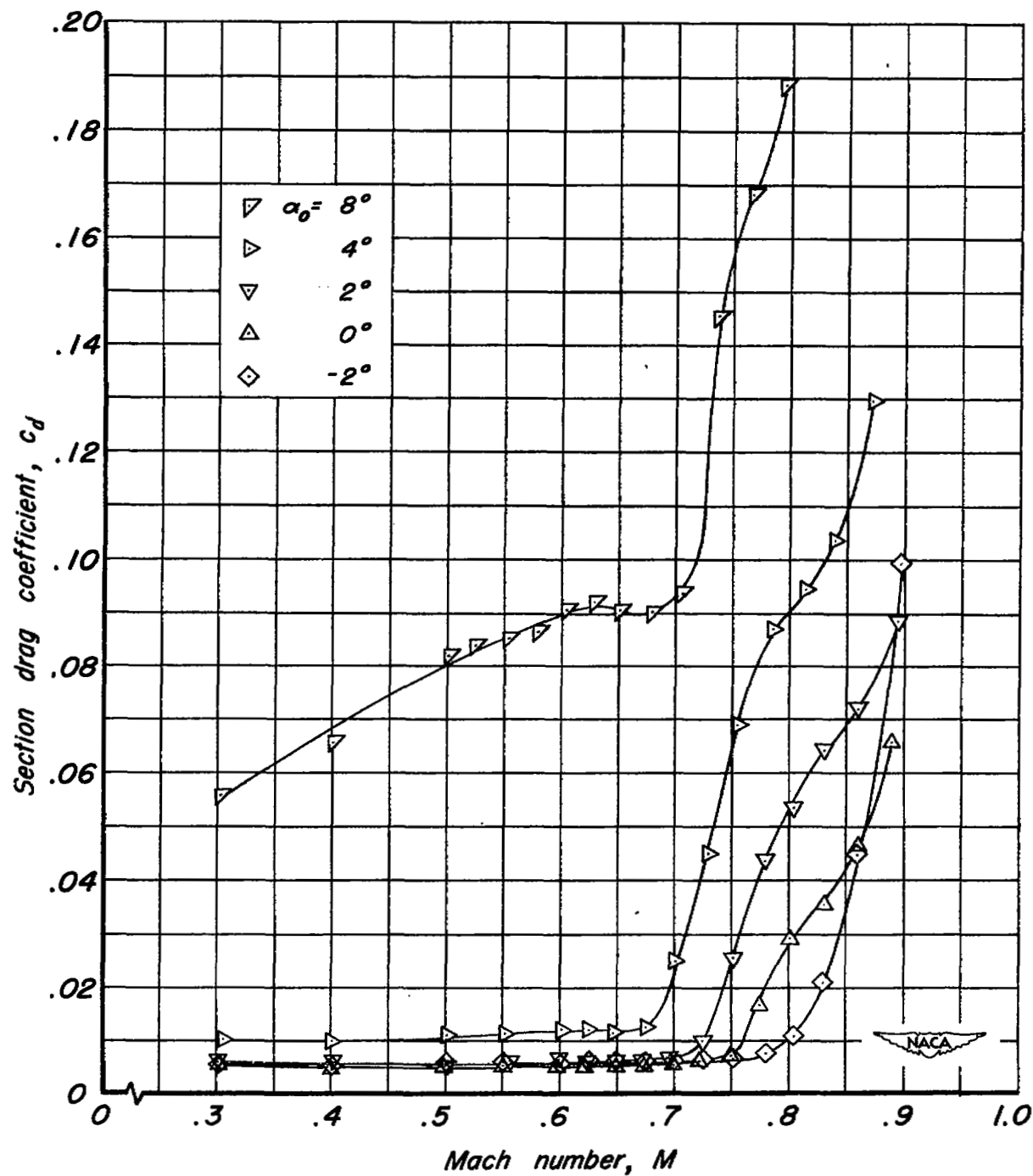
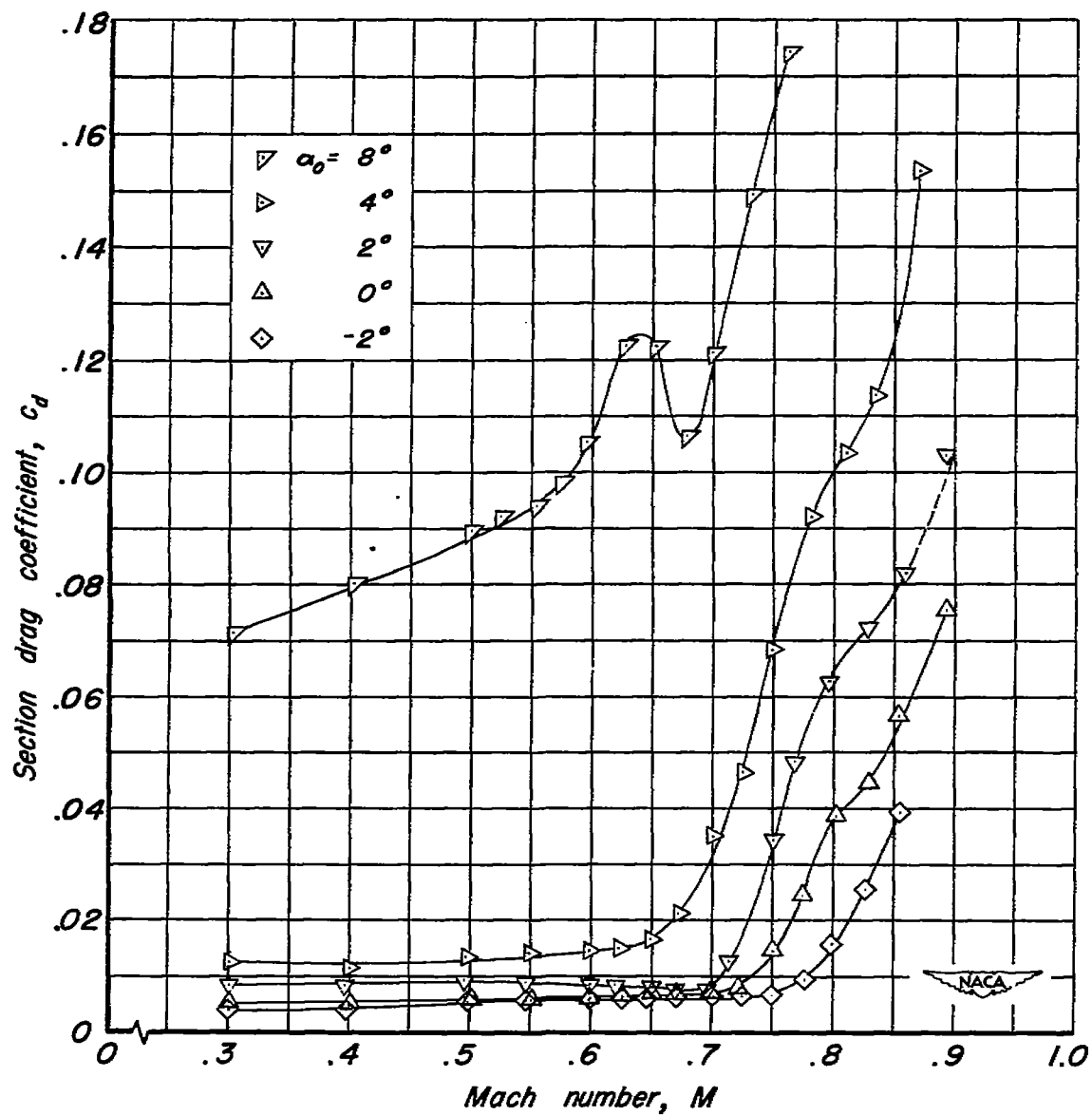


Figure 2 : Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.



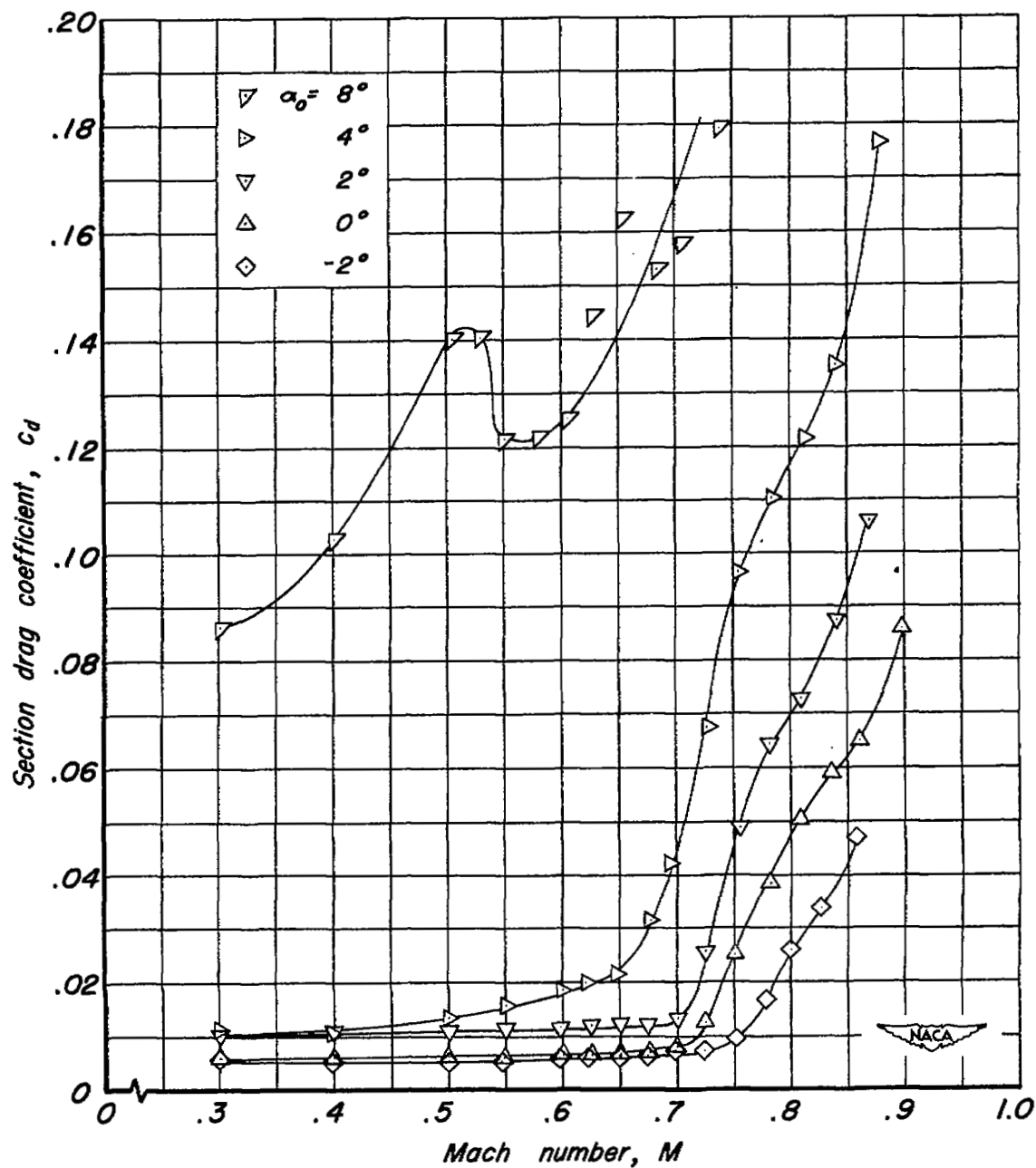
(e)  $\delta_f = 4.0^\circ$

Figure 2 : Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.



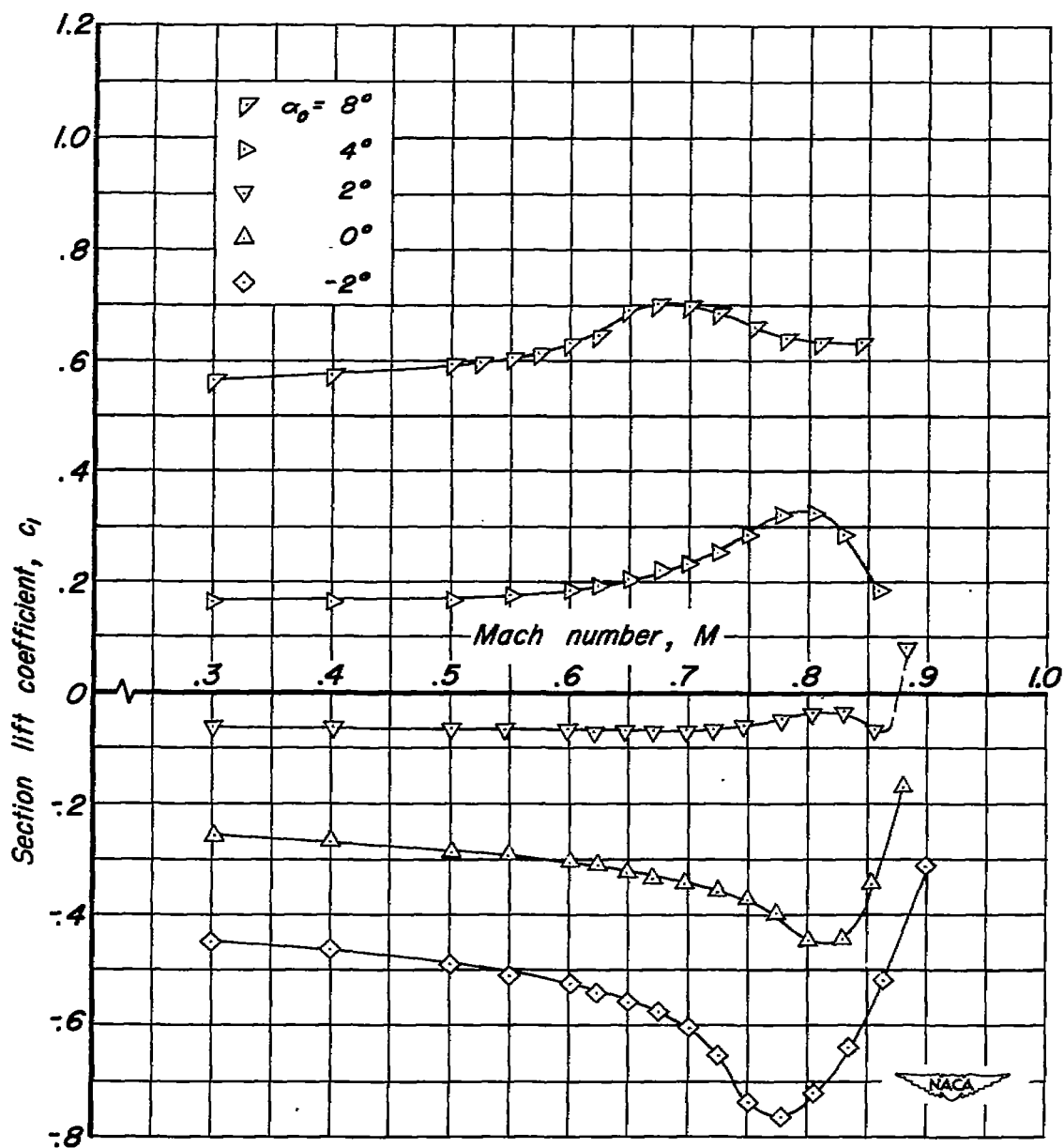
(f)  $\delta_f = 6.9^\circ$

Figure 2 - Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.



(g)  $\delta_f = 10.6^\circ$

Figure 2 - Concluded. NACA 65-210 airfoil with a 10-percent-chord plain flap.



(a)  $\delta_f = -11.8^\circ$

Figure 3.-The variation of section lift coefficient with Mach number for the NACA 65-210 airfoil with a 10-percent-chord plain flap.



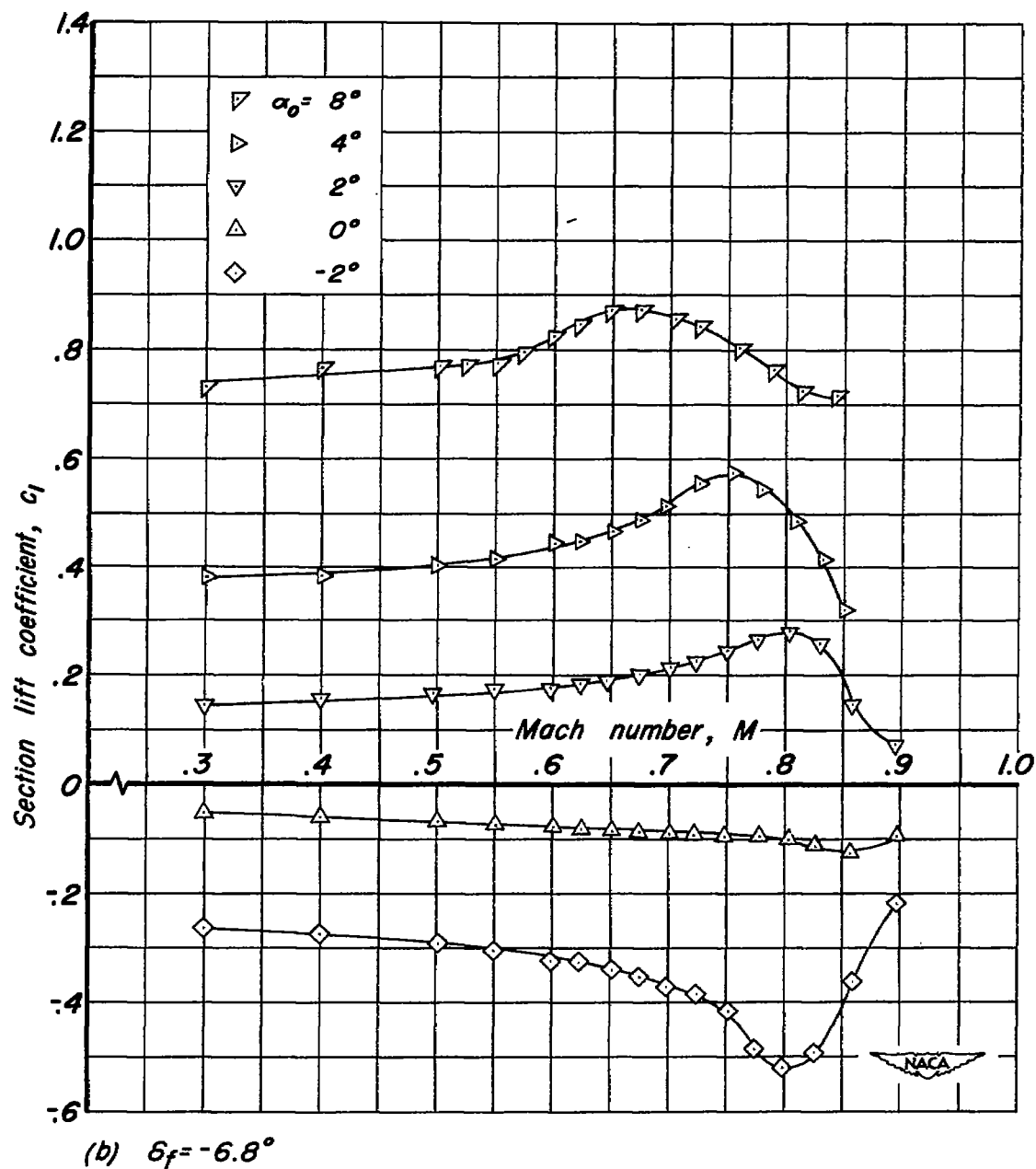


Figure 3.- Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.

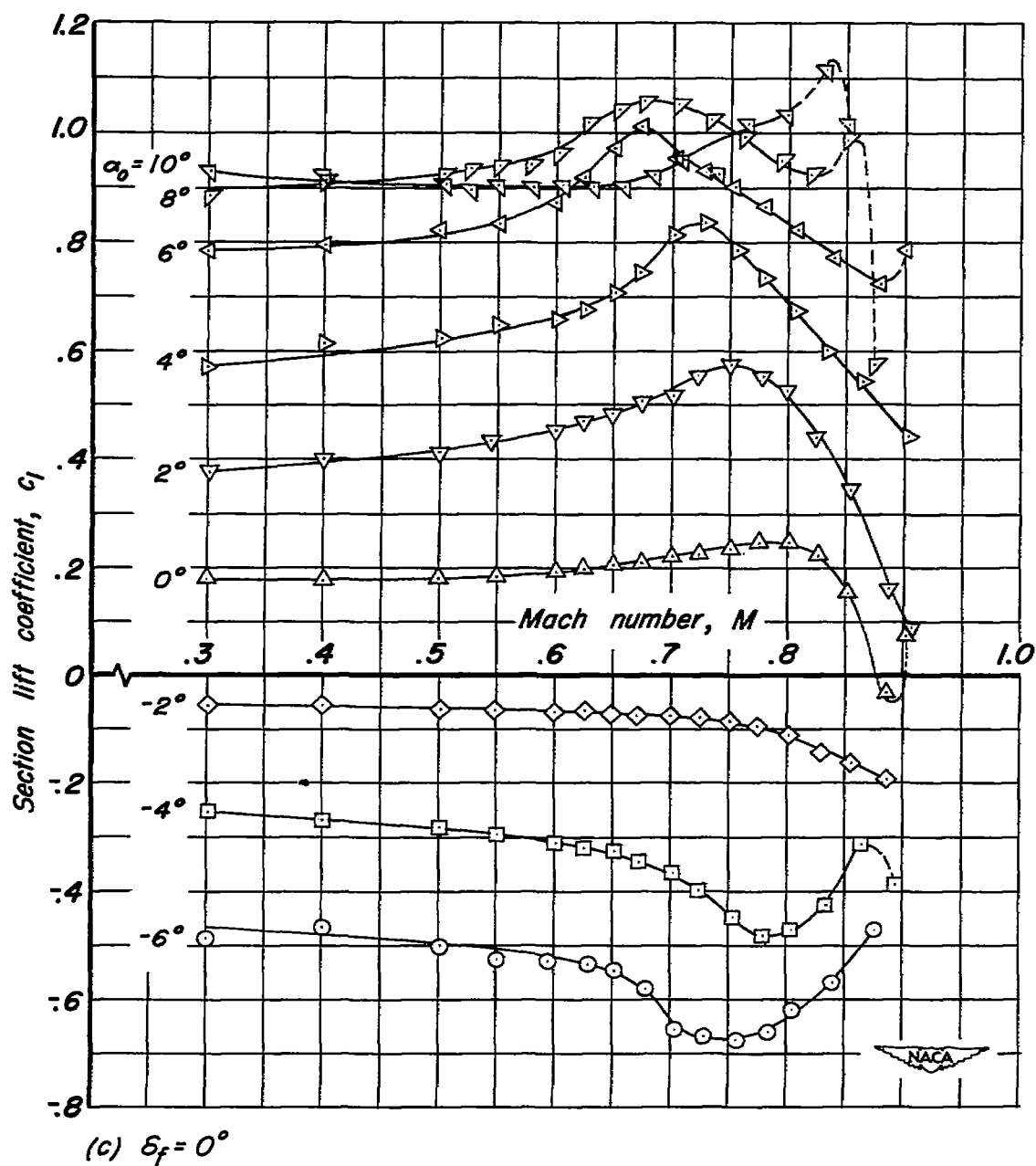
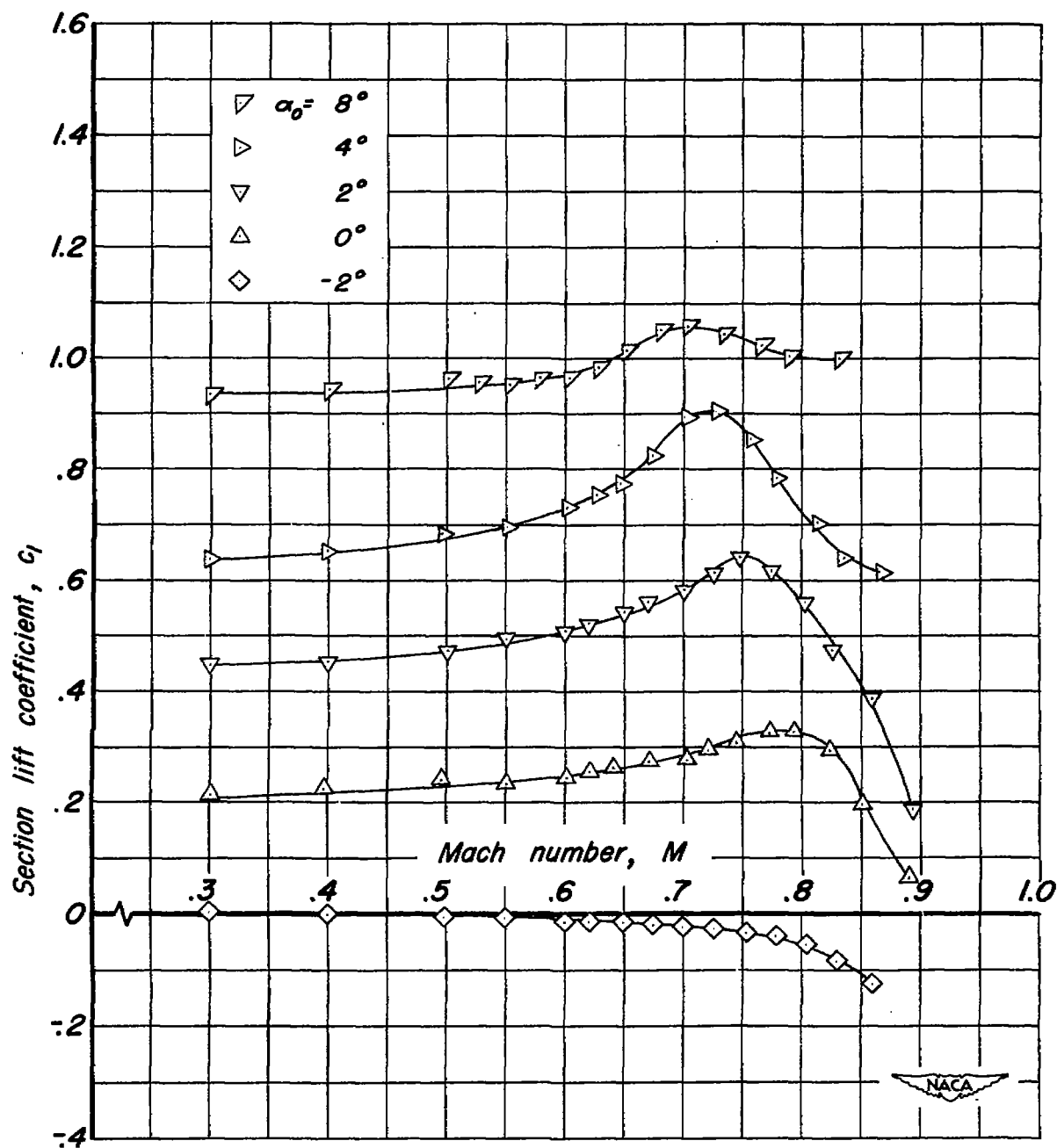
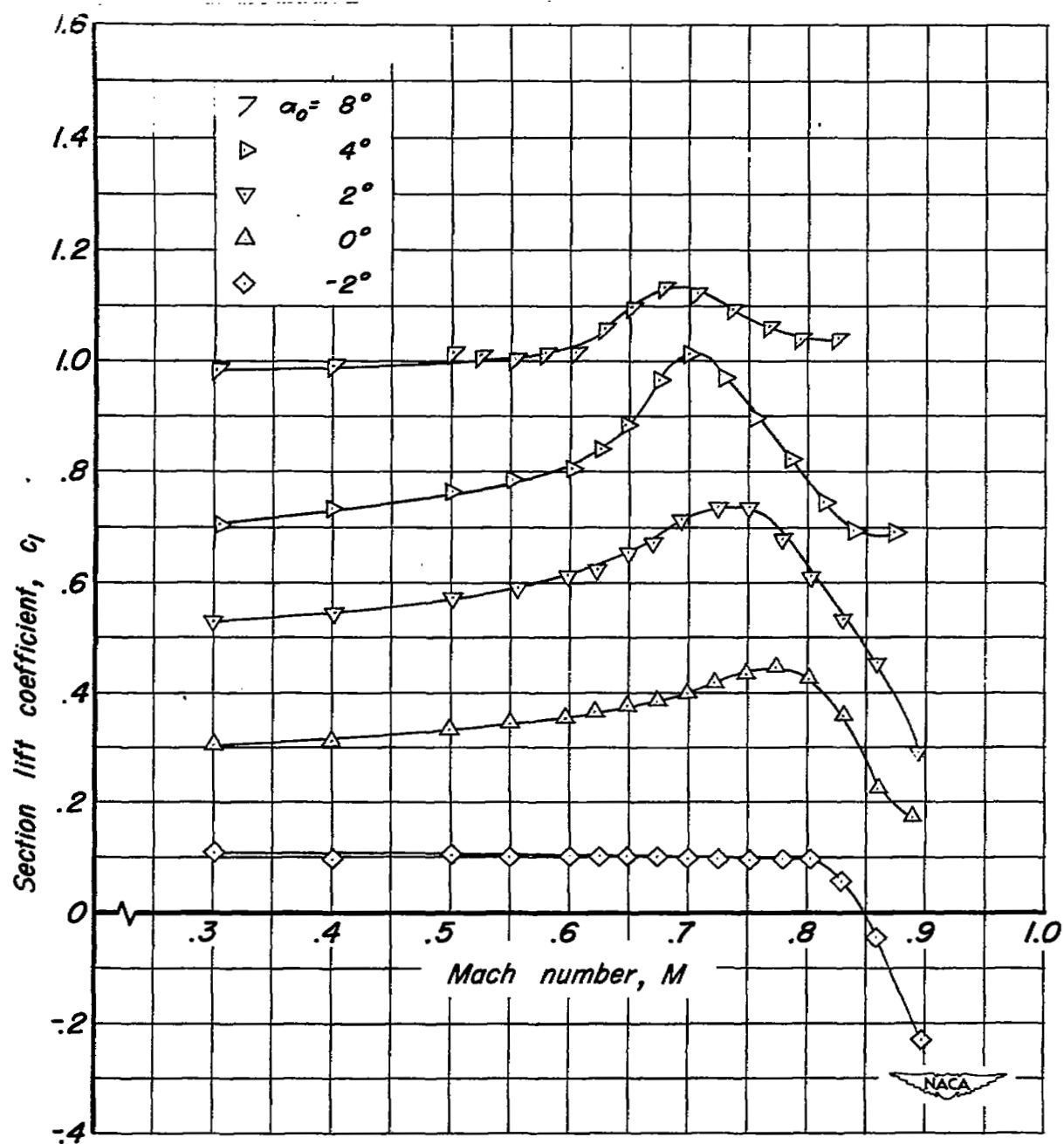


Figure 3.-Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.



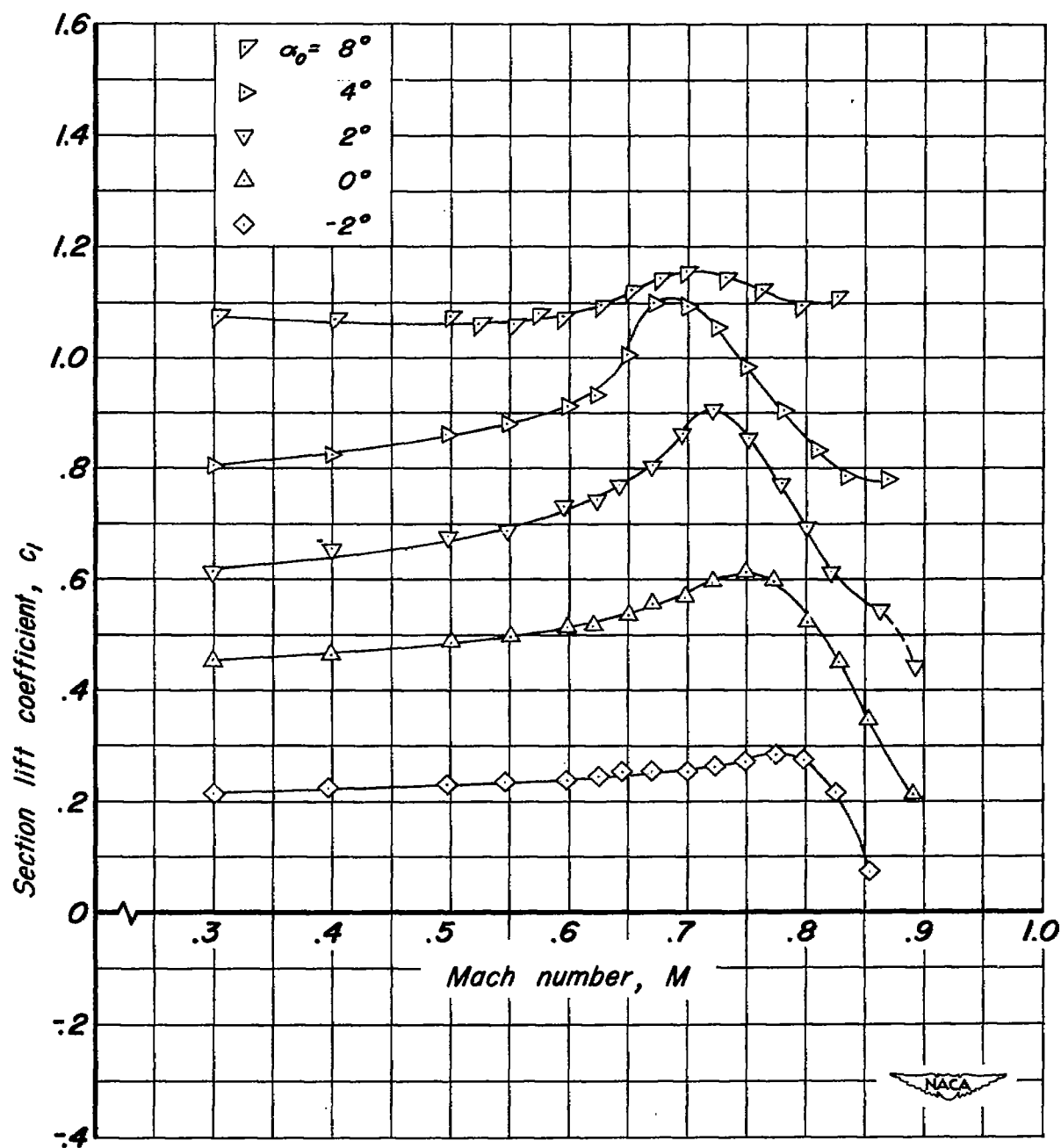
(d)  $\delta_f = 1.7^\circ$

Figure 3 - Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.



(e)  $\delta_f = 4.0^\circ$

Figure 3-Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.



(f)  $\delta_f = 6.9^\circ$

Figure 3 - Continued. NACA 65-210 airfoil with a 10-percent-chord plain flap.

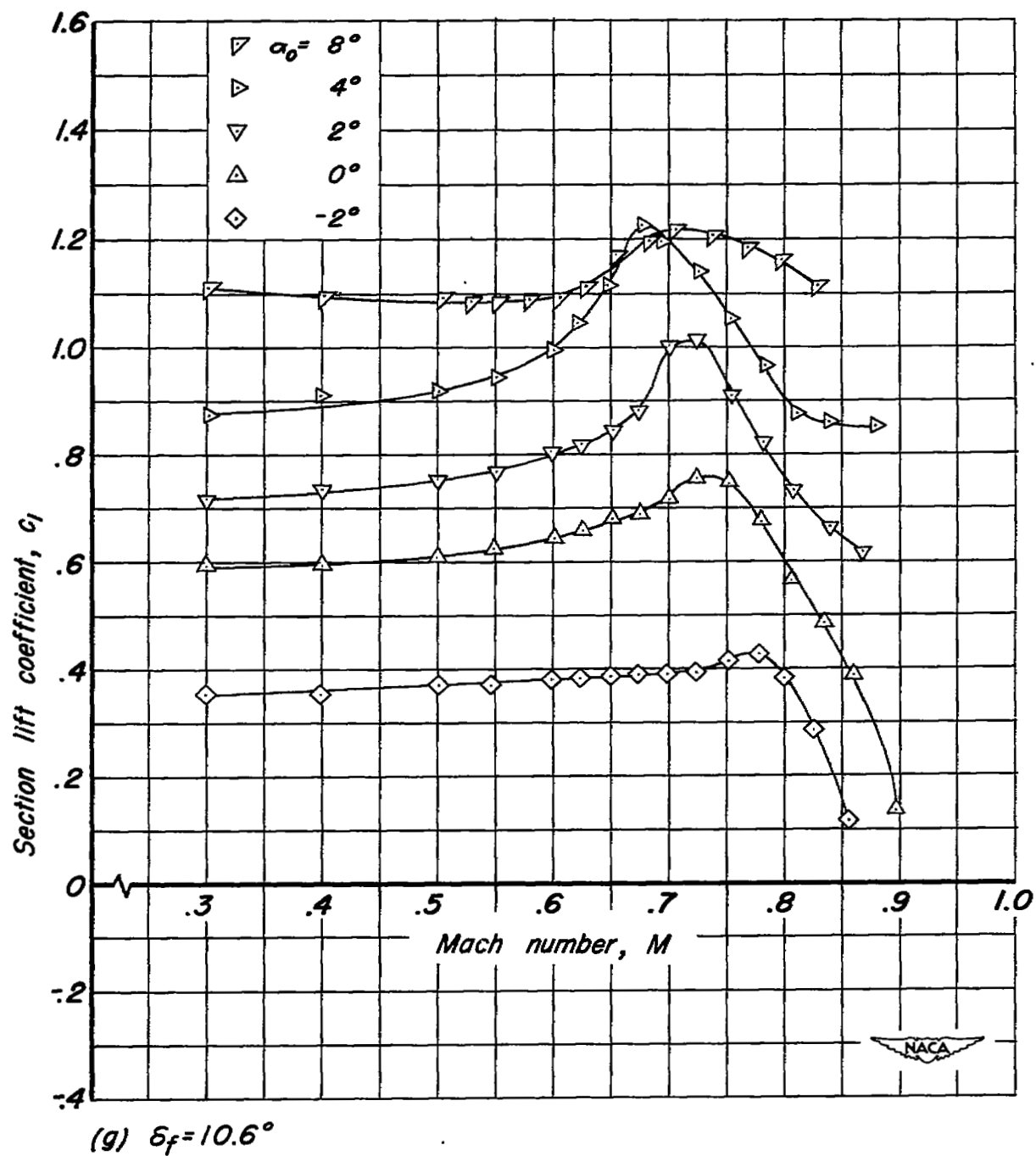
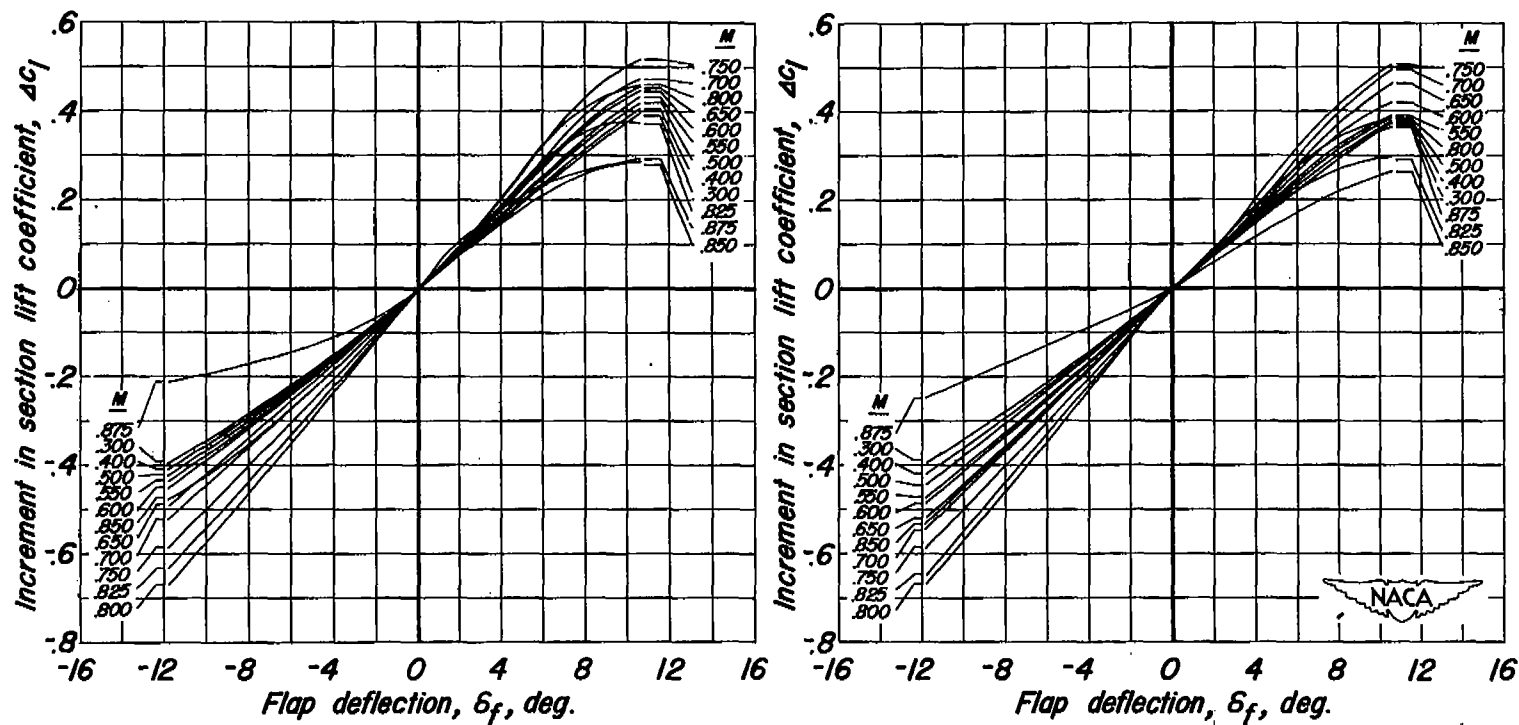


Figure 3 - Concluded. NACA 65-210 airfoil with a 10-percent-chord plain flap.



(a)  $\alpha_0$  for  $c_l = 0$ ,  $\delta_f = 0$

(b)  $\alpha_0$  for  $c_l = 0.2$ ,  $\delta_f = 0$

Figure 4.-The variation of increment in section lift coefficient with flap deflection at various Mach numbers for the NACA 65-210 airfoil with a 10-percent-chord plain flap.

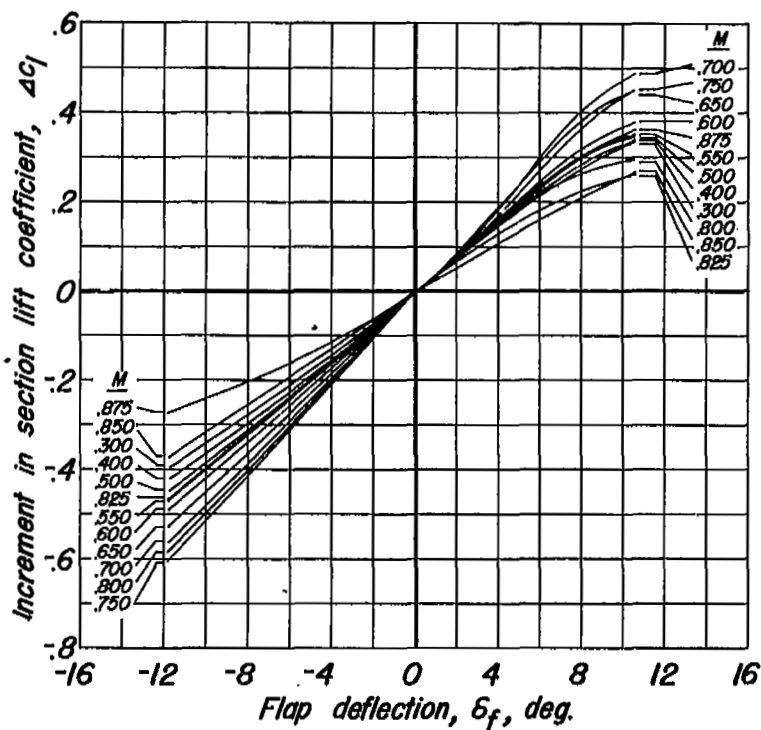
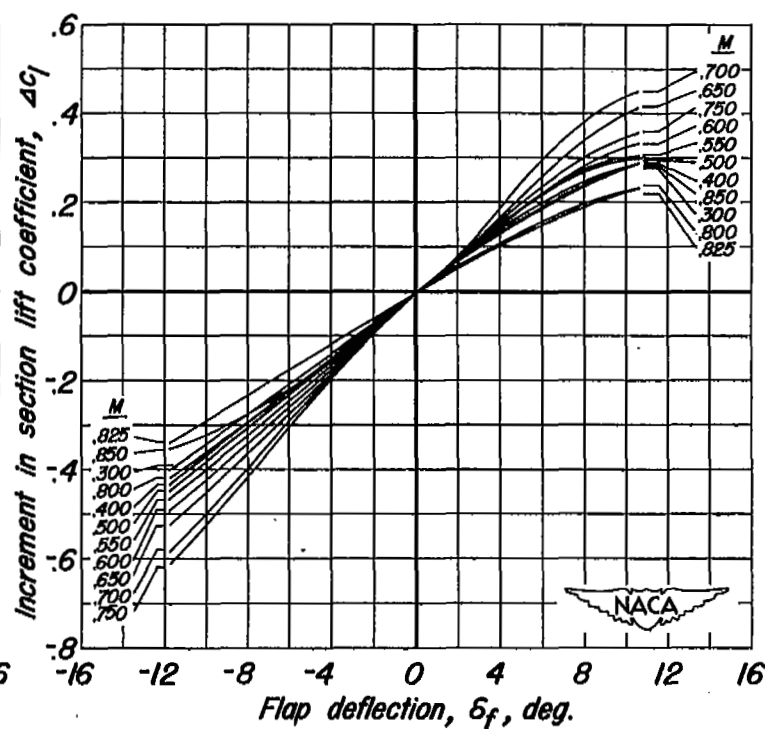
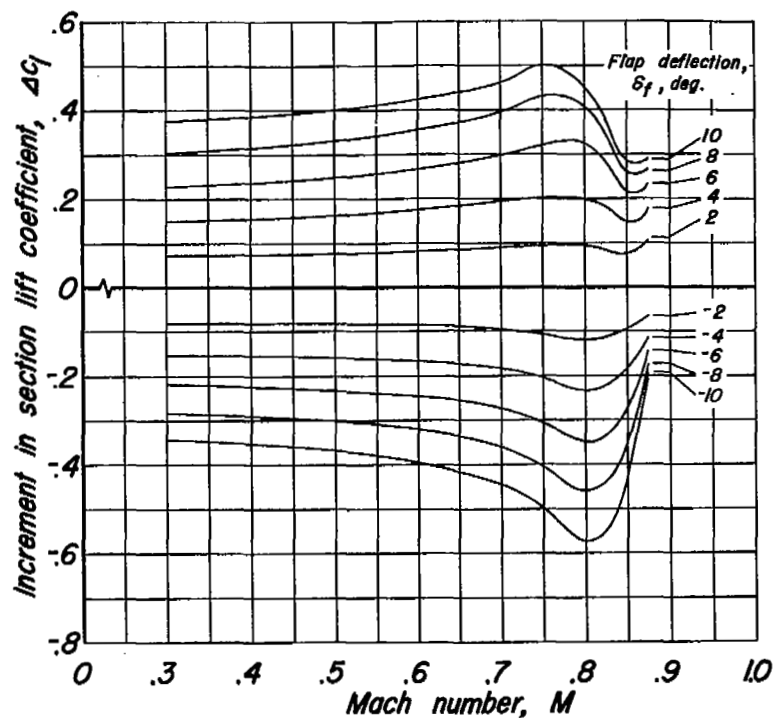
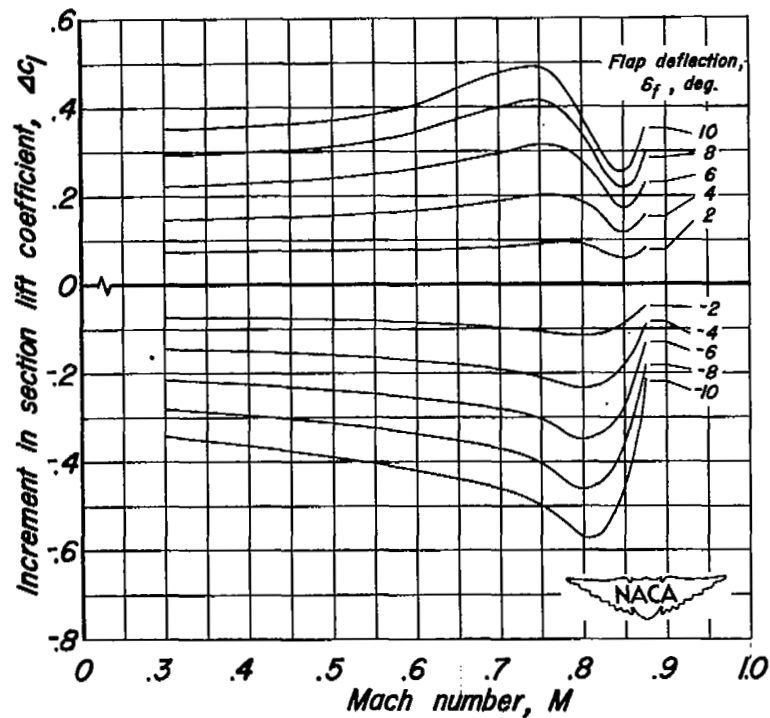
(c)  $\alpha_0$  for  $c_l = 0.4$ ,  $\delta_f = 0$ (d)  $\alpha_0$  for  $c_l = 0.6$ ,  $\delta_f = 0$ 

Figure 4.-Concluded. NACA 65-210 airfoil with a 10-percent-chord plain flap.





(a)  $\alpha_0$  for  $c_l = 0$ ,  $\delta_f = 0$



(b)  $\alpha_0$  for  $c_l = 0.2$ ,  $\delta_f = 0$

Figure 5.-The variation of increment in section lift coefficient with Mach number at various flap deflections for the NACA 65-210 airfoil with a 10-percent-chord plain flap.

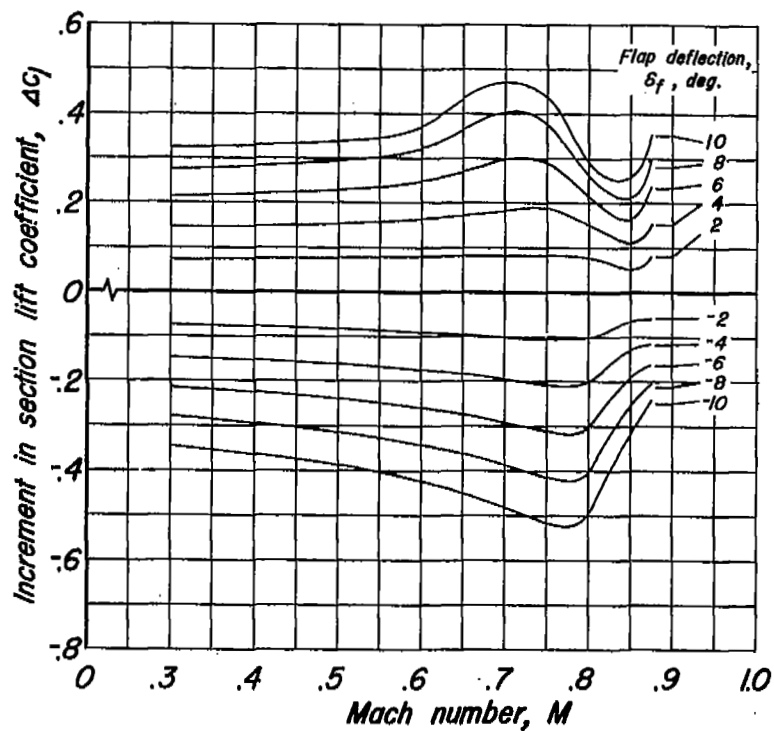
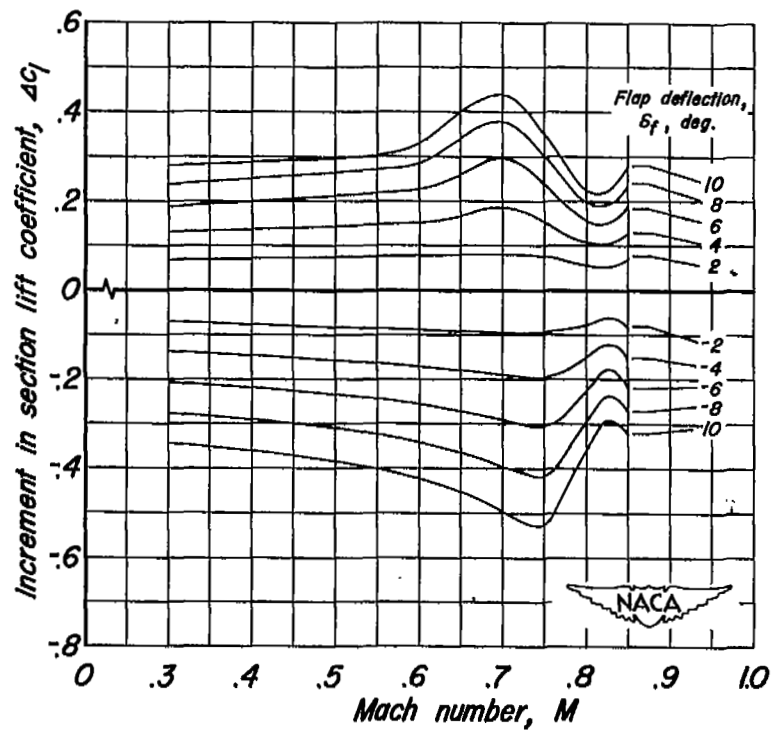
(c)  $\alpha_0$  for  $c_l = 0.4$ ,  $\delta_f = 0$ (d)  $\alpha_0$  for  $c_l = 0.6$ ,  $\delta_f = 0$ 

Figure 5.-Concluded. NACA 65-210 airfoil with a 10-percent-chord plain flap.

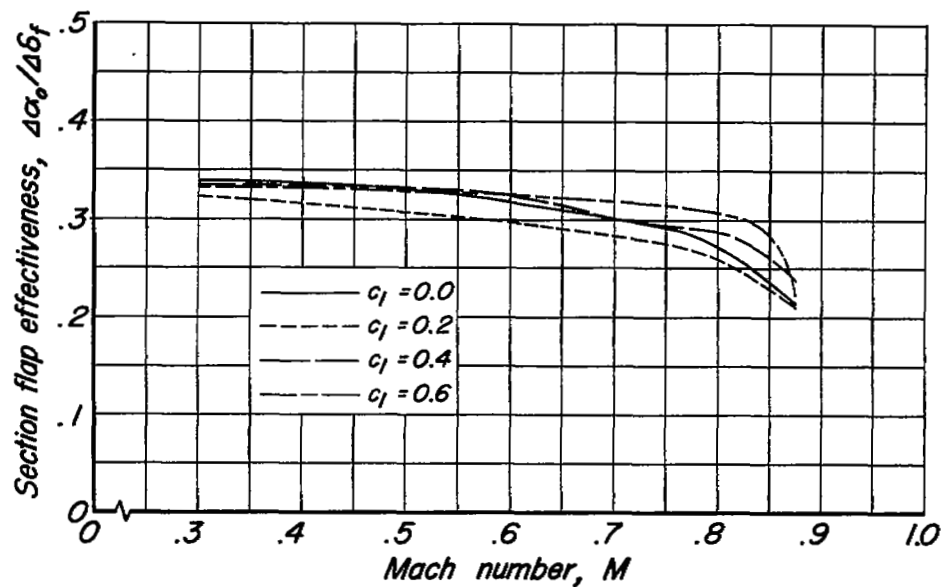


Figure 6.-The variation of flap effectiveness with Mach number at various lift coefficients for the NACA 65-210 airfoil with a 10-percent-chord plain flap.

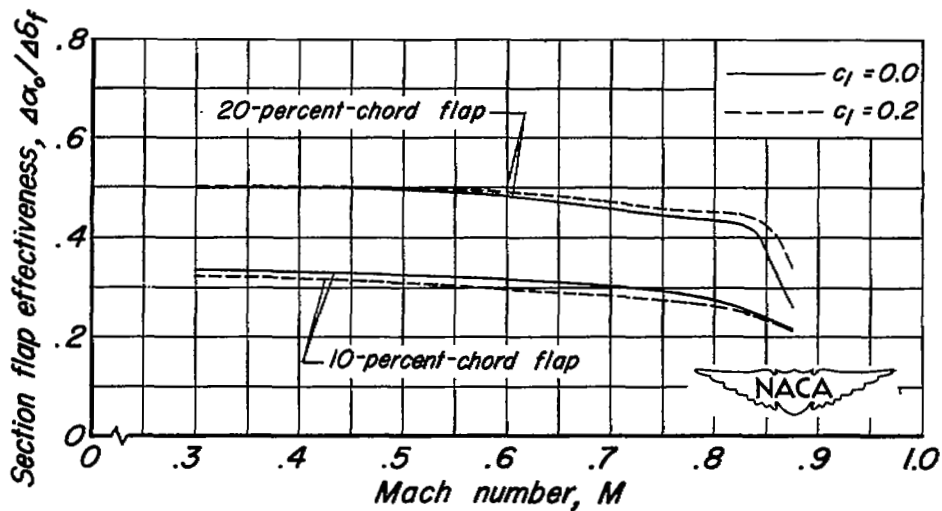


Figure 7.-Comparison of the variation in flap effectiveness with Mach number at lift coefficients of 0 and 0.2 for the NACA 65-210 airfoil with 10-percent- and 20-percent-chord plain flaps.

NASA Technical Library



3 1176 01434 4502